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13 ABSTRACT (Maximum 200 words) It is more important now, than ever before, for U.S. Navy surface combatants to be integrated from a readiness assessment and reporting point of view. This is because surface combatants are now necessarily more complex as they are combined with other surface ships, submarines, and aircraft into Battle Groups (BG) under control of Composite Warfare Commanders (CWC). These BG Commanders need readiness status data and information to accomplish their required functions. Furthermore, BGs are combined into Battle Forces (BF) and BF Commanders must be provided with readiness data and information to support their decision making requirements. Finally, National Command Authority (NCA) must be kept apprised of the readiness status of all units. If the total ship (comprised of a combat system and a hull, mechanical and electrical (HM&E) system) does not have adequate readiness information available at its interface with the BG, the BG Commander cannot be provided with the required readiness status, i.e., a "chain is only as strong as its weakest link." The Shipboard Readiness Reporting System (SRRS) involves readiness assessment and reporting at the total ship level, improved by integrating readiness reporting and assessment of the combat and hull, mechanical and electrical systems comprising the total ship. The two areas of concentration in SRRS are "levels of reporting" and "data distribution." The area of "Levels of reporting" is emphasized in this paper. Published: <i>Proceedings, 9th Ship Control Systems Symposium, September 1990.</i>					
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SHIPBOARD READINESS REPORTING SYSTEM (SRRS) - LEVELS OF REPORTING

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1. ABSTRACT

It is more important now, than ever before, for U. S. Navy surface combatants to be integrated from a readiness assessment and reporting point of view. This is because surface combatants are now necessarily more complex as they are combined with other surface ships, submarines and aircraft into Battle Groups (BG) under control of Composite Warfare Commanders (CWC). These BG Commanders need readiness status data and information to accomplish their required functions. Furthermore, BGs are combined into Battle Forces (BF) and BF Commanders must be provided with readiness data and information to support their decision making requirements. Finally, National Command Authority (NCA) must be kept apprised of the readiness status of all units.

If the total ship (comprised of a combat system and a hull, mechanical and electrical (HM&E) system) does not have adequate readiness information available at its interface with the BG, the BG Commander cannot be provided with the required readiness status, i.e. "a chain is only as strong as its weakest link."

The Shipboard Readiness Reporting System (SRRS) involves readiness assessment and reporting at the total ship level, improved by integrating readiness reporting and assessment of the combat and hull, mechanical and electrical systems comprising the total ship. The two areas of concentration in SRRS are "levels of reporting" and "data distribution." The area of "Levels of reporting" is emphasized in this paper.

2. INTRODUCTION

The Shipboard Readiness Reporting System (SRRS) will improve readiness reporting and assessment in surface combatants (missile launching capable surface ships). The SRRS is applicable to both new construction and in-service surface combatants.

Surface combatants are more complex now than ever before because:

(a) the threats to these ships have increased in quantity, capabilities and sophistication and the ships must be capable of coping with the increased threat,

(b) the surface combatant is combined with other ships, submarines, aircraft and land and space assets to form coordinated/cooperative Battle Groups and Battle Forces and the ships' design must accommodate these combined coordinated/cooperative operations and

(c) ship's spaces, systems and personnel are widely distributed throughout the ship for survivability and other reasons which creates new operational and maintenance problems and magnifies existing problems.

In Navy surface ships there are several tactical (operational) and technical (maintenance) spaces separated by relatively large distances. Examples include; (a) Combat Information Center (CIC), (b) a central location for controlling maintenance, (c) Damage Control Central (DCC) and (d) Work Centers (where operational equipment such as radars and sonars are located). Operational and maintenance readiness status data must be shared among these spaces in real (or near real) time using a common data base. These spaces could be linked via one or more local area networks (LAN) thereby facilitating the distribution of mission-specific doctrine, configuration alternatives, test schedules and scenarios and maintenance, mode, state and configuration reports. These data should be appropriately formatted, stored in a common data base, filtered in accordance with users' needs and then provided to tactical and technical users in a timely fashion.

Three technical problems are addressed by the SRRS:

(a) Accurate assessment of surface combatant capability and required corrective maintenance is difficult and time-consuming.

(b) There are no design standards for testing and subsequently reporting readiness status and there is no consistent methodology for collecting, formatting, distributing and displaying readiness status reports.

(c) As spaces, equipment and personnel are separated throughout the ship to improve survivability, data distribution (communications) must be improved to sustain proper operations and maintenance.

3. READINESS REPORTING PATHS

A U. S. Navy surface combatant is part of a readiness reporting and assessment hierarchical structure (architecture) that extends in both an upward and downward direction from the ship. Figure 1 shows this tiered hierarchical structure.

The reporting path above the ship includes the Battle Group (BG), Battle Force (BF) and National Command Authority (NCA). Below the ship are the systems, elements, equipments, cabinets, chassis, printed circuit boards (modules) and the components mounted on those modules. The ordering above and below the ship is important and the items within each level must be correctly identified. This is accomplished as part of the levels of reporting portion

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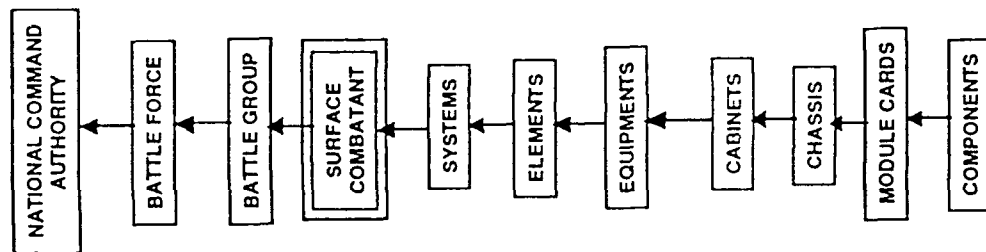


FIGURE 1. READINESS REPORTING AND ASSESSMENT HIERARCHICAL STRUCTURE

of SRRS.

It is a premise in this paper that any readiness status reporting above the ship, for use by higher authority, can be no better than what is available from within the ship, i.e., available at the ship/BG interface. The reason for this premise is that "a chain is only as strong as its weakest link." If a ship doesn't have its own complete readiness status, it can't very well report it to higher authority. There are programs that are attempting to improve readiness reporting and assessment above the ship level using artificial intelligence, data fusion and other techniques. However, if there are readiness reporting and assessment shortcomings within the ship, they must be corrected at the source of the problem (within the ship) to ensure that complete, correct, accurate and timely readiness reports can be made to higher authority.

4. CURRENT SRRS IMPLEMENTATION ANALYSES

Eventually, SRRS could be integrated into all surface ships, not just surface combatants, and could even be extended to cover other types of platforms and units. Figure 2 provides an overall Navy readiness reporting and assessment picture from National Command Authority down to the material, personnel and logistics readiness of each ship's constituent system.

Currently, SRRS is being applied to the areas shown vertically along the left side of Figure 2. SRRS is initially being applied to the material readiness of the combat system in surface combatants. Selected threads in specific Naval Warfare Mission Areas have been completed as part of the levels of reporting portion of SRRS. As the combat system thread analysis is completed, the results can be combined with similar hull, mechanical and electrical (HM&E) efforts ongoing at the David Taylor Research Center (DTRC). The combination of the combat and HM&E systems will complete the total ship, since these are the two constituent systems comprising a surface combatant.

5. SRRS CONSTITUENTS

The SRRS is being developed in two parts. One part is "levels of reporting" and the second part is "data distribution." Integration of these two parts of SRRS is being accomplished during all phases of SRRS development.

Levels of reporting involves identifying each level of the ship's systems hierarchical structure and the test requirements at each level needed to ensure appropriate readiness reporting to all system users (operators and maintainers).

Data distribution involves identifying all system nodes, the necessary fusion of readiness data and information at each system node and the data distribution (communications) interfaces between system nodes. The combination of message protocol definition, establishing interface requirements, identifying system nodes and precisely defining message traffic based on

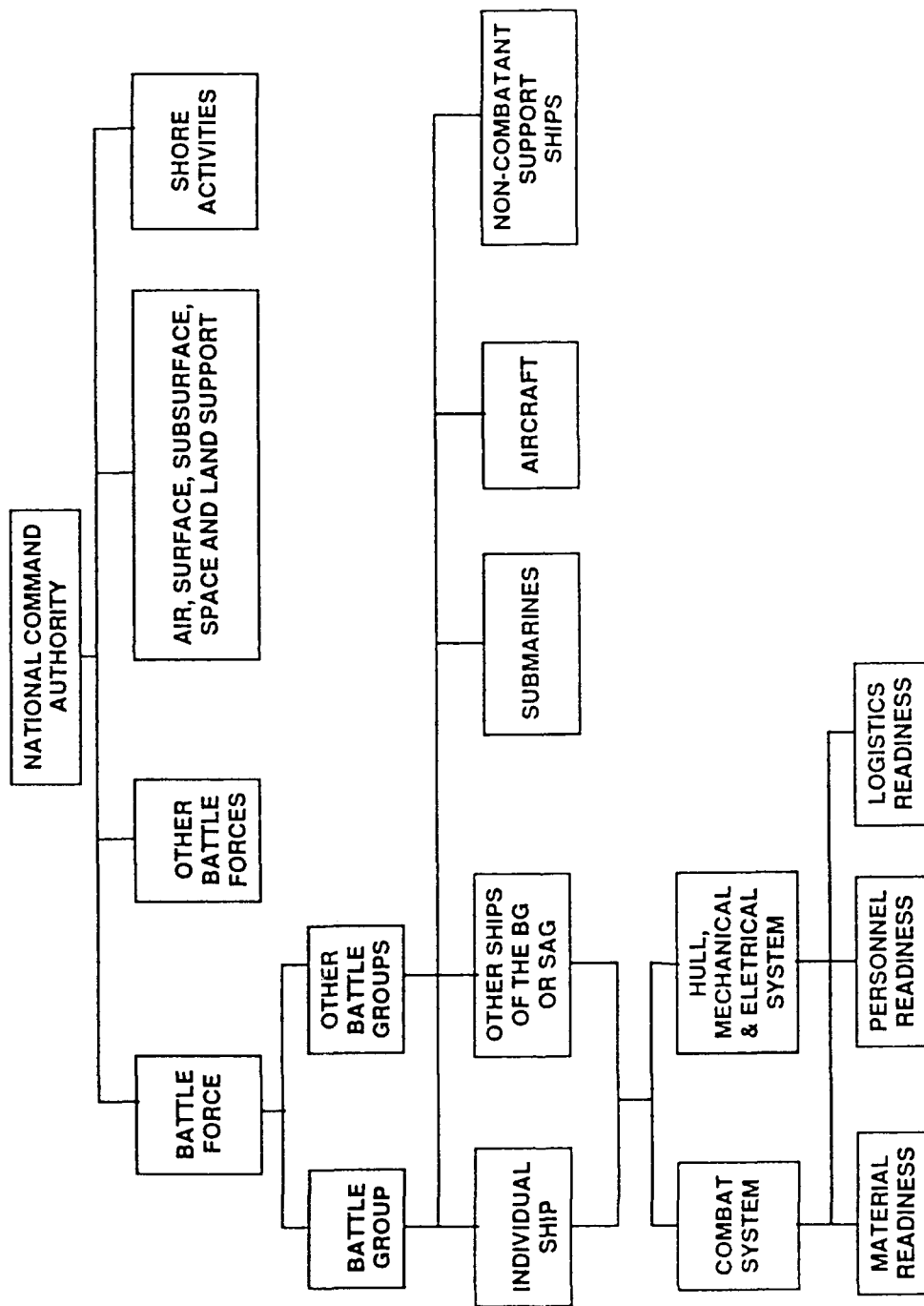


FIGURE 2. OVERALL NAVY READINESS REPORTING AND ASSESSMENT

users' needs should result in the right kind, and right amount, of readiness data and information being provided to each user in a timely fashion. This paper deals primarily with the levels of reporting portion of SRRS.

6. MISSION AREAS, CAPABILITIES, FUNCTIONS AND OBJECTIVES

Frequently, mission areas, capabilities, functions and objectives are mixed and merged with elements and equipments when a readiness reporting and assessment hierarchy (architecture) is being developed. These elements and equipments support the mission areas, provide the capabilities, perform the functions and accomplish the objectives. This mixing results in inappropriate positioning of many items in the surface combatant hierarchy. It is important to be able to distinguish between mission areas, capabilities, functions and objectives and Figure 3 attempts to sort this out.

Figure 3 shows the Naval Warfare Mission Areas across the top horizontal row. The middle horizontal row illustrates the common functions used in each warfare area and the bottom horizontal row contains the detailed objectives of each function. Figure 3 is not sufficiently detailed to completely distinguish between mission areas, capabilities, functions, objectives, elements and equipments. Therefore, Figure 4 was prepared to complete the picture by relating the functions and functional groupings to the elements and equipments that accomplish the functions.

7. COMBAT SYSTEM GENERAL HIERARCHICAL STRUCTURE

In order to provide proof of concept and reduce task accomplishment cost and manpower to manageable levels, the combat system was initially emphasized for SRRS. Figure 5 indicates the exponential growth in numbers of combat system constituents in a tiered hierarchical structure. While this hierarchical structure is complex, it reflects an actual combat system functional order and must be completed before proceeding further. The bad news is that each system must be precisely and correctly structured in a format that successively includes system, elements, equipments, cabinets, chassis, LRUs, modules and components. The good news is that this only has to be done once for each system and updated only to indicate system modifications.

Ship's readiness status data and information is derived from test results of the ship's systems at various levels within the system's hierarchical architecture (system, element, equipment, cabinet, chassis, etc.). Tests are conducted at all levels of the combat system from the system down to the components mounted on module cards and chassis. Test results are then used to report readiness status for both the operation and maintenance of the combat system. As part of SRRS, a typical combat system "top-down" architecture was developed so that the impact of faults and errors at low levels could be assessed at all higher levels (operational readiness status reporting). Also, when fault and error symptoms are indicated at any level of the combat system hierarchical structure, fault diagnosis is required at lower levels to isolate and correct the fault (maintenance readiness status reporting). Since it is

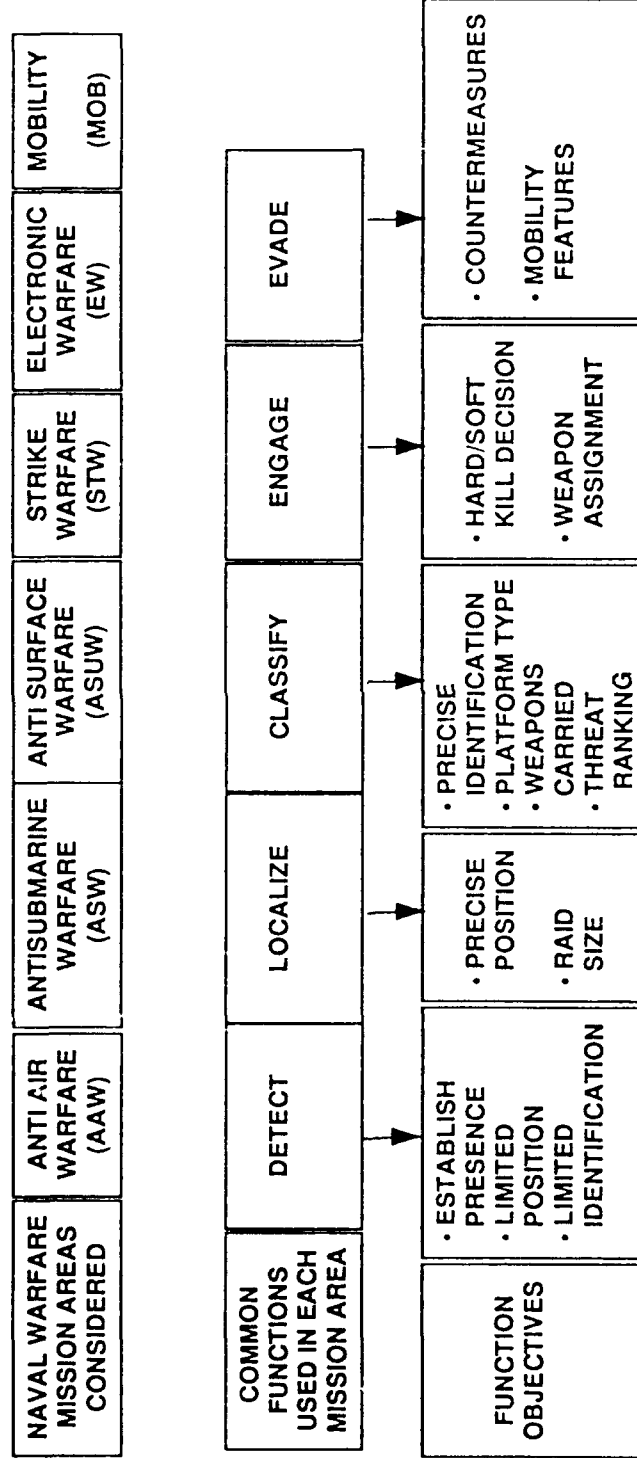


FIGURE 3. MISSION AREAS, FUNCTIONS AND OBJECTIVES

FUNCTIONS	FUNCTIONAL GROUPINGS	ELEMENTS	EQUIPMENTS
DETECTION	SENSORS	SEARCH RADARS SONARS	AIR SEARCH RADARS SURFACE SEARCH RADARS MULTIFUNCTION RADARS ELECTRONIC SUPPORT MEASURES EQUIPMENT ACTIVE/PASSIVE SONARS ACTIVE SONARS PASSIVE SONARS
IDENTIFICATION	COMMAND & CONTROL COMMUNICATIONS	COMMAND & DECISION INTER/INTRA COMMUNICATIONS EQUIPMENT	ENGAGEMENT CONTROL EQUIPMENT DIRECT ENCRYPTED VOICE/DATA LINKS RELAY ENCRYPTED VOICE/DATA LINKS UNDERWATER COMMUNICATIONS EQUIPMENT INTERNAL COMMUNICATIONS EQUIPMENT AIRCRAFT LINK AND PROCESSING SHIPBOARD EQUIPMENT
ENGAGEMENT	WEAPONS	WEAPON POINTING ACCURACY EQUIP. ARMAMENT AMMUNITION	MULTIFUNCTION RADARS FIRE CONTROL RADARS LAUNCHERS GUN MOUNTS TORPEDO TUBES MISSILES TORPEDOES DEPTH CHARGES
EVASION	COUNTER-MEASURES	ACTIVE/PASSIVE COUNTERMEASURES	ACOUSTIC DECOYS CHAFF ACTIVE ELECTRONIC COUNTERMEASURES

FIGURE 4. FUNCTIONAL RELATIONSHIP TO ELEMENTS AND EQUIPMENTS

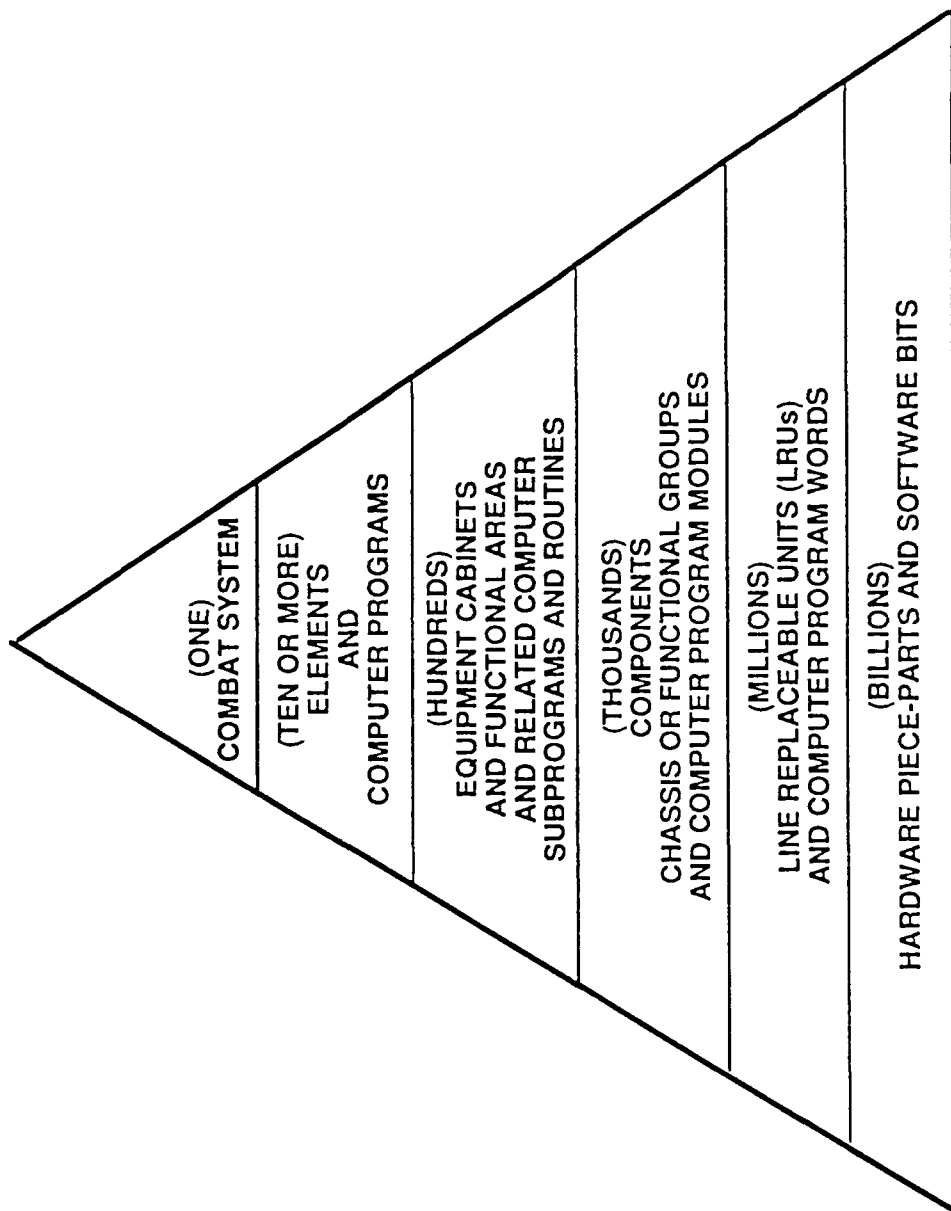


FIGURE 5. COMBAT SYSTEM HIERARCHY

necessary to be able to go both up and down from any level within the combat system hierarchy whenever a fault or error symptom occurs, it is essential that the combat system hierarchical structure be defined in advance of the design process. This will also allow identification of levels which require additional testing, levels in which redundant testing exists, and "hardspots" from a testing and readiness status reporting point of view.

8. COMBAT SYSTEM READINESS REPORTING AND ASSESSMENT PROBLEMS

Current combat systems in surface combatants have readiness reporting and assessment problems inherent in their design. SRRS must avoid these problems in future combat system designs and correct them in existing fleet ships. Examples include:

(a) Inability to differentiate between an equipment that has failed, an equipment that is in other than the normal operational mode or state and an equipment that is not fully initialized.

(b) Testing periodicity and fault detection and isolation coverage is substantially different from equipment to equipment and this is frequently not accounted for in current readiness reporting and assessment approaches.

(c) Operational and maintenance data and information are mixed and indiscriminately provided to both tactical (operational) and technical (maintenance) personnel. This is confusing and the data needs to be filtered to make it more meaningful to the user and more concisely presented.

(d) The readiness terminology used varies widely from equipment to equipment, so that different terms are used to mean precisely the same thing.

9. COMBAT SYSTEM THREAD

For purposes of this paper, the SRRS levels of reporting methodology is illustrated using a single thread within the combat system. The Antisubmarine Warfare (ASW) mission area was selected for the illustration. The selected thread extends from the combat system level down to the ASW Naval Warfare Mission Area. Then, an overall ASW hierarchy was developed to identify the ASW constituents at each level. Next, the thread extends down from ASW to the hull mounted and towed array sonars in which both active and passive detections are included. Finally, a detailed functional thread called "Localization of ASW Contacts Using Sonobuoys" is shown and described.

9.1 Combat system to ASW

Currently, the combat system is pretty well partitioned in terms of the Naval Warfare Mission Areas that it supports. There are procedures and doctrine that accurately localize problems to the specific Naval Warfare Mission area that contains the problem. Figure 6 is an overall ASW hierarchy identifying the ASW functions (detect, localize, etc.) across the top row. The next

<u>DETECT</u>	<u>LOCALIZE</u>	<u>CLASSIFY</u>	<u>ATTACK</u>	<u>DESTROY</u>	<u>AVOID ENEMY TORPEDOES</u>
SENSORS ELEMENT	DISPLAY SHARING/COMPUTER SWITCHING ELEMENT		WEAPONS ELEMENT		TORPEDO COUNTERMEASURES ELEMENT
ACTIVE SONAR EQUIPMENT	PASSIVE SONAR EQUIPMENT	SHIPBOARD SONOBUOY EQUIPMENT	CONTROL EQUIPMENT	TORPEDO LAUNCHING EQUIPMENT	AUDIO EQUIP.
				DEPTH CHARGE LAUNCHING EQUIP	BUBBLE MAKING EQUIP
AN/SQS-53C (ACTIVE)	AN/SQS-53C (PASSIVE)	AN/SQQ-28 AN/SRQ-4 AN/SKR-4 AN/ARR-75 LAMPS MK I LAMPS MK III	AN/SQQ-89 MK 116 MOD 7 ICOM EXCOM	VLS/ASROC OTS TORPEDOES LAMPS MK I LAMPS MK III	AN/SLQ-25 (NIXIE) PRAIRIE MASKER
	AN/SQR-19 (PASSIVE)				

FIGURE 6. SURFACE COMBATANT ASW HIERARCHY

row identifies the ASW elements and the third row from the top generally identifies each equipment grouping. Finally, at the bottom of Figure 6, is a listing of each ASW equipment that belongs to each equipment grouping. The purpose of this ASW hierarchy is to ensure that nothing is omitted when developing the SRRS levels of reporting for the selected ASW thread.

9.2 ASW to sonars

The purpose of the sonars is to perform the ASW surveillance function. In other words, active and passive hull mounted and towed array sonars must detect underwater contacts. Figure 7 shows this portion of the selected combat system thread starting at the ASW Naval Warfare Mission Area and extending down to the hull mounted and towed array sonars.

Notice, in Figure 7, that there are other Naval Warfare Mission Areas, but this thread deals only with ASW. There are other functions, but this thread deals only with DETECT (limited localization and identification are accomplished as shown by dashed box). There are also other ASW detection capabilities, but this thread deals only with active and passive sonars.

9.3 Localization of ASW contacts using sonobuoys

Once an ASW contact has been either actively or passively detected using the hull mounted or towed array sonars, a decision might be made to localize the ASW contact using sonobuoys. Figure 8 contains this portion of the selected combat system thread and shows the required functions and equipments to localize ASW contacts using sonobuoys.

In order to Localize ASW Contacts Using Sonobuoys, it is necessary to

- (a) DEPLOY SONOBUOYS,
- (b) PROCESS SONOBUOY DATA FROM OWNERSHIP, and
- (c) PROCESS SONOBUOY DATA FROM OTHER SOURCES.

These functions are shown within dotted boxes in Figure 8. The equipments that accomplish the functions are shown within solid boxes. The equipments are laid out in a tiered hierarchical architecture dictated by how the outputs, inputs and interfaces are positioned during normal system operation. Functional dependency of one equipment on another is a prime consideration of the layout.

There are five sources for deploying sonobuoys; lamps MK I, lamps MK III, carrier based helicopters, fixed wing aircraft and ownship. The fixed wing aircraft include P-3s and S-3s. In order to deploy the sonobuoys effectively, the tactical and technical users must be advised, via readiness reporting, of the availability of each of the five sources for deploying sonobuoys.

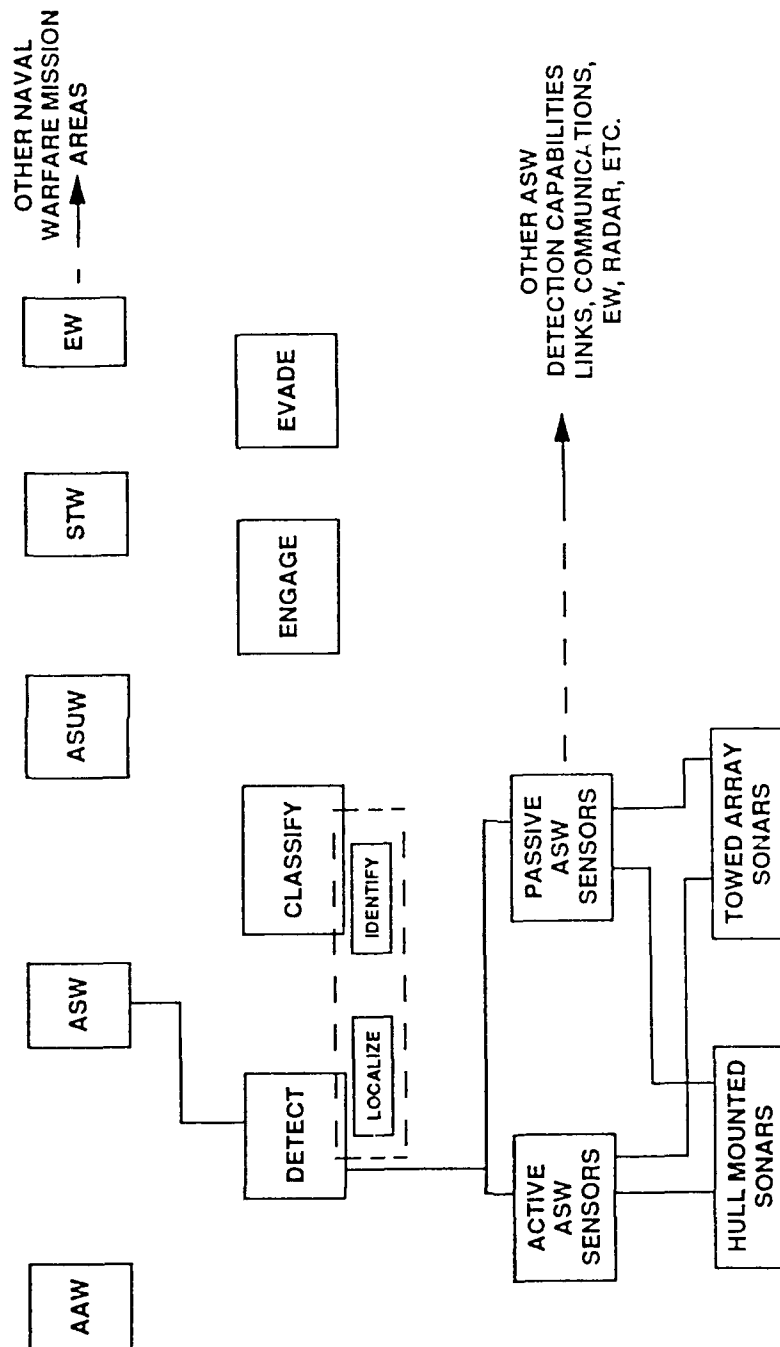


FIGURE 7. COMBAT SYSTEM THREAD - ASW TO SONARS

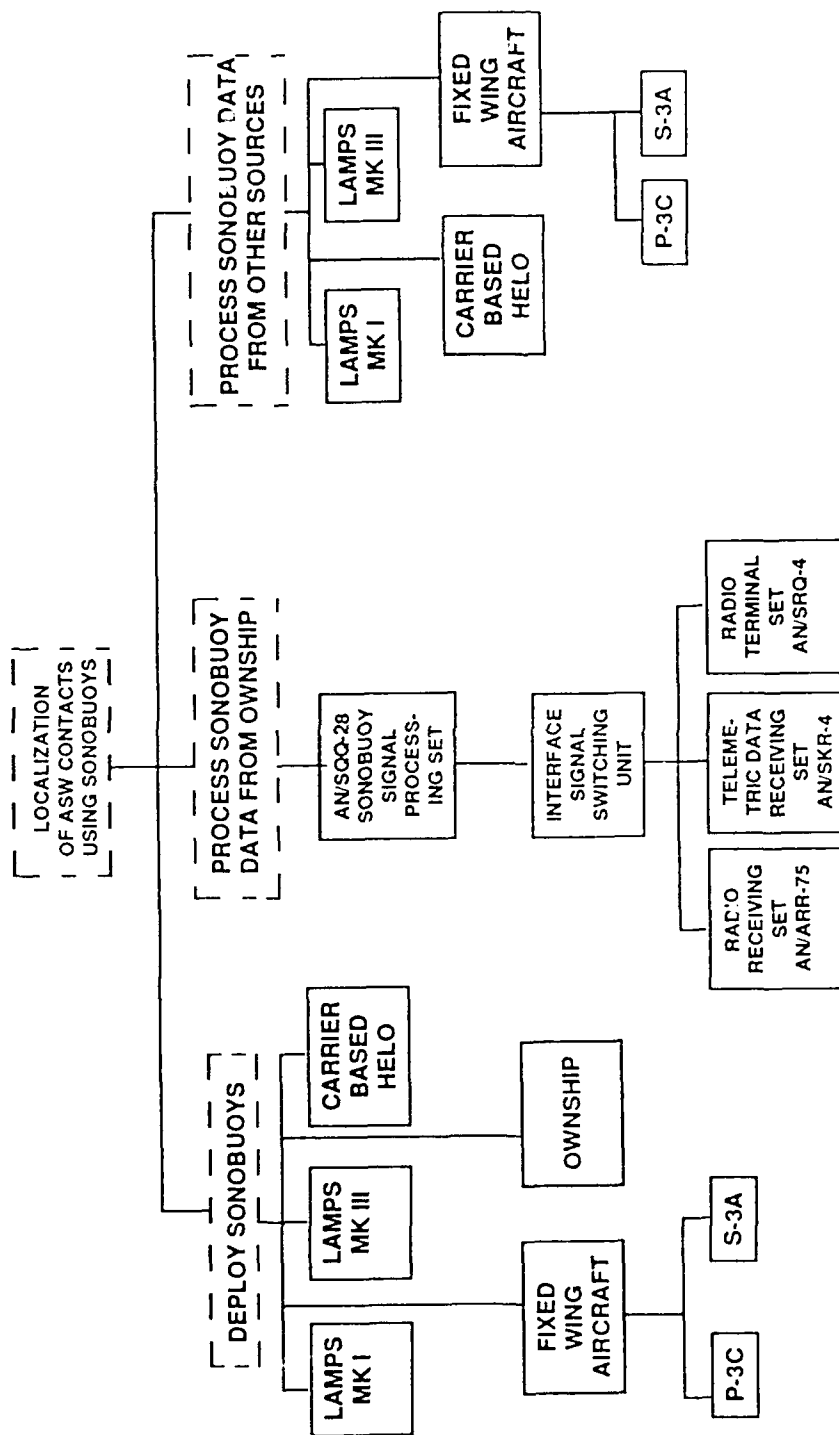


FIGURE 8. LOCALIZATION OF ASW CONTACTS USING SONOBUOYS

Once sonobuoys are deployed by one of the five sources, the ship must be capable of processing the data from the deployed sonobuoys. The equipments shown in Figure 8 (AN/SQQ-28, Interface Signal Switching Unit, AN/ARR-75, AN/SKR-4, AN/SRQ-4) all can play a role in processing sonobuoy data. The ARR-75 links the sonobuoys directly to the ship. The AN/SKR-4 is the link between lamps MK I and the ship while the AN/SRQ-4 is the link between lamps MK III and the ship. Once again, the tactical users must be informed of the operational readiness status of each of these three ASW equipments so that they can make intelligent decisions on how to best get sonobuoy data to the ship for processing. Notice that if the Interface Signal Switching Unit or the AN/SQQ-28 is hard down, shipboard processing of sonobuoy data will not be possible.

There is a path, shown on the top right of Figure 8, that enables processing of sonobuoy data from other sources off-ship. This includes lamps MK I, lamps MK III, carrier based helicopters, and fixed wing aircraft (P-3s or S-3s).

The essence of this example is that the readiness status of each equipment to support each element must be known. Furthermore, the impact of any element or equipment problems must be assessed to determine current ship capabilities. Included in the capabilities category are deploy sonobuoys, process sonobuoy data, etc. as shown by the dashed boxes of Figure 8 while the solid boxes of Figure 8 represent elements and equipments.

10. TOOL FOR SIMPLIFYING THE HIERARCHY

Existing combat systems consist of hundreds of equipments. Each equipment falls into one of three categories.

Category 1. Test results are collected at the equipment level and are transmitted to the element (and higher levels);

Category 2. Test results are collected at the equipment level but are not transmitted to the element;

Category 3. Test results are not adequately collected at the equipment level.

The readiness data flow diagram, Figure 9, illustrates a method for analyzing and correcting (when required) existing systems and providing concise, accurate, and timely readiness reports to tactical and technical users. Test results from equipments in Category 1 only require minor formatting before entry into a common data base and, as shown in Figure 9, the test results are sent directly to a DATA FORMATTER. Test results from Category 2 equipment require interface modifications between the equipment and higher levels. This is accomplished by the CREATE INTERFACE block in Figure 9. Equipment in Category 3 must be modified to collect the test results and the interface must also be modified to pass these test results to the DATA FORMATTER. Note that the SRRS, a product of top-down design, would result in Cate-

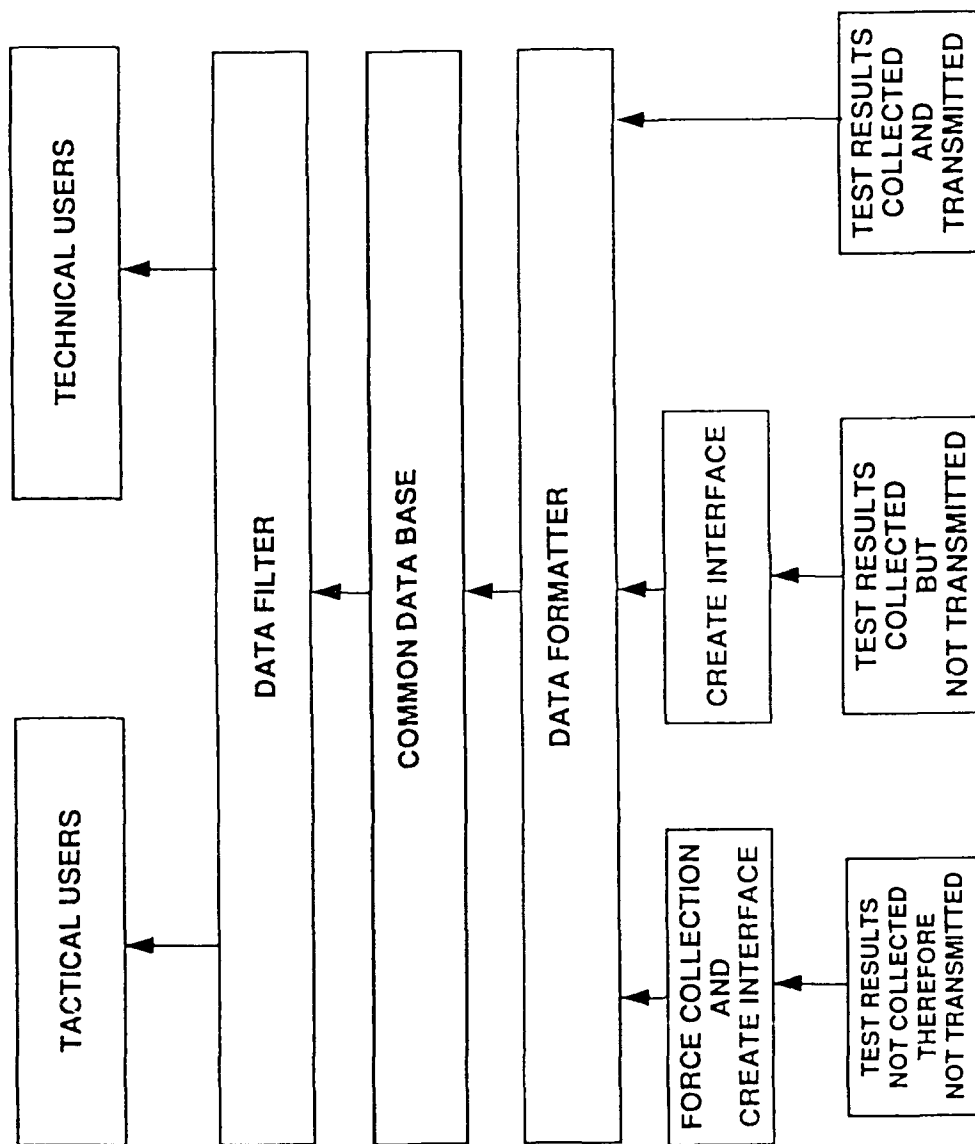


FIGURE 9. READINESS DATA FLOW DIAGRAM

gory 1 equipments for newly designed combat systems and would identify Category 2 and 3 equipments for modification for in-service combat systems.

The DATA FORMATTER corrects and standardizes inputs to the COMMON DATA BASE. The DATA FILTER then organizes the readiness related data and information into two groups; one that satisfies tactical (operational) user requirements and a second that satisfies technical (maintenance) user requirements. Finally, appropriate readiness data and information are delivered for display to tactical and technical users in a concise, accurate and timely fashion.

11. FUTURE PLANS

The intent is to expand SRRS both horizontally and vertically and to transition SRRS from its current 6.2 (Exploratory Development) status. The horizontal expansion entails completing other ASW threads, completing combat system threads in other Naval Warfare Mission Areas and, finally, integrating combat system threads with similar threads developed for the HM&E system. The vertical expansion of SRRS involves integrating the SRRS levels of reporting effort with ongoing fault detection, diagnostics and isolation efforts. This should lead to a complete top to bottom hierarchical architecture and best use of test results at all levels for operational and maintenance readiness status reporting.

11.1 Horizontal expansion

Most of the horizontal expansion of SRRS involves completing other ASW threads and developing combat system threads in other Naval Warfare Mission Areas (AAW, ASUW, STW, EW, etc.). However, the most important horizontal expansion of SRRS involves the integration of readiness reporting and assessment of the combat and hull, mechanical and electrical (HM&E) systems. NOSC is accomplishing the SRRS task under the auspices of the Office of Naval Technology (ONT) Code 226. The David Taylor Research Center (DTRC) is working on a task called Condition Based Maintenance (CBM) for HM&E equipment under the same 6.2 block funding that covers SRRS. Both NOSC and DTRC are involved with the NAVSEA sponsored Damage Control Management System (DCMS) that might serve as a vehicle to transition SRRS. This could result in the combat and HM&E systems being integrated from a readiness reporting and assessment point of view.

11.2 Vertical expansion

Some of the threads developed as part of SRRS levels of reporting are not yet complete through all levels of the hierarchy. The Naval Research Laboratory (NRL) is working on a 6.2 block funded task involving artificial intelligence applications of fault isolation diagnostics for the AN/SQS-53 Hull Mounted Sonar. This could serve as an excellent vertical expansion of a specific ASW thread if these two portions of an overall thread could be properly integrated.

Other related programs include: the AEGIS Operational Readiness Test System (ORTS), the Combat System Technical Operations Manual (CSTOM), the Engineering and Combat System Operational Sequencing Systems (EOSS and CSOSS - separately and independently developed), the Integrated Diagnostics Support System (IDSS) and many other programs too numerous to mention here. These would all support vertical expansion of SRRS.

11.3 Transition

It is a goal of every program and project at some point in time, to transition toward eventual in-service use and SRRS is no exception. The Damage Control Management System (DCMS), directed by NAVSEA, seems to be an ideal program to transition SRRS into. DCMS is principally used in combat and especially after a ship has sustained battle damage. Under these conditions there is no time for repairing failures through long corrective procedures like removal/replacement or alignment. DCMS must continuously know the precise readiness status of surface combatant systems and also must know which rapid corrective action can be taken or what alternate resources can be employed.

SRRS covers the entire readiness reporting and assessment picture including areas of fault tolerance and rapid recovery. DCMS only has time for rapid recovery corrective action where fault tolerant design features are provided. These functions must be identified within the SRRS levels of reporting and integrated into DCMS. Figure 10 indicates a sorting method that could be used for this purpose, thereby taking the first steps of integrating SRRS with DCMS.

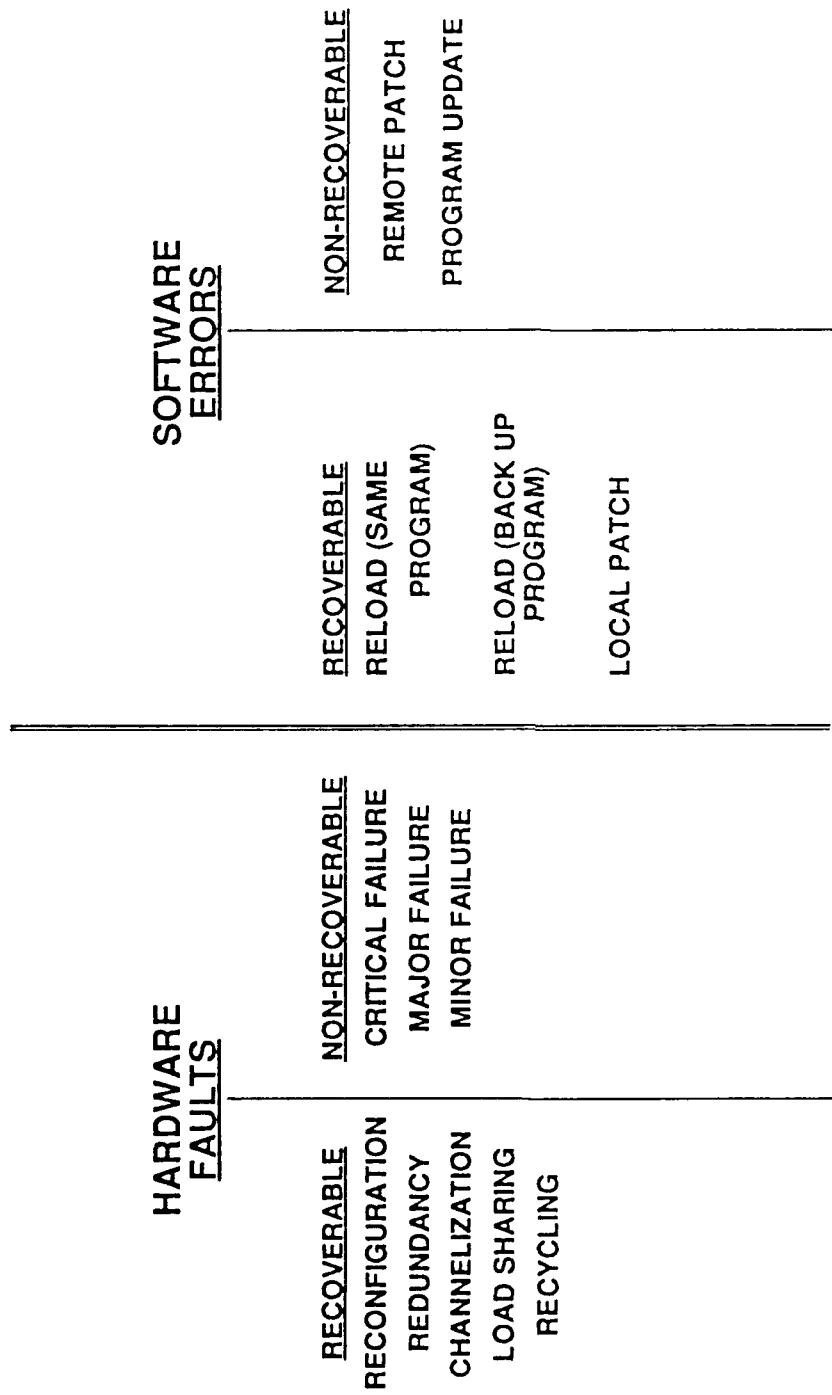


FIGURE 10. SYSTEM MALFUNCTIONS SORTED BY RECOVERY TIMES